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Meteorological Support to Spaceport Operations

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Abstract

The Spaceflight Meteorology Group (SMG) Weather Bureau, ESSA, is responsible for providing weather support in connection with the Manned Spaceflight Program. This weather support is broadly categorized into: (1) Mission support, and (2) Non-mission support.

Prior to a manned space flight, the Cape Kennedy Section of the SMG provides pertinent weather forecasts to the various users, such as the Mission Director and the Launch Director. After launching, the distribution of forecasts for recovery purposes becomes the primary responsibility for another section of SMG.

With the progression from Project Mercury to the Gemini program and to the Apollo program, the need for non-mission weather support increased. Many weather-critical operations are affected by minute weather changes, which are continuously reported to the various test conductors during pre-launch tests, together with interpretations of their impact upon the test.

Of primary importance is the occurrence of strong winds. In this regard the Saturn V launch vehicle poses special problems. The Mobile Launcher and the Mobile Service Structure do not provide protection to the vehicle against strong winds. Therefore, whenever the design wind speed of the space vehicle is likely to be exceeded, it is expected that as assembled vehicle standing on the launch pad would be returned to the Vehicle Assembly Building (VAB). Such wind speed would ordinarily be associated with tropical cyclones passing near the Cape Kennedy area.

Discussion

Since the beginning of recorded history, man has availed himself of other living creatures, or inanimate objects within his environment to provide a means of getting to and fro with a minimum of effort on his own part. Tracing his progress from one form of transportation to another, we find that with each succeeding improvement in his vehicle, he had made himself more vulnerable to the various characteristics of his atmospheric environment.

History does not record whether prehistoric man first straddled a floating log, or the back of one or another of the family of living creatures from which he had only recently evolved. Whichever may have been the case, he soon learned that at times his newly discovered modern convenience was of no use to him, having been incapacitated by some prank of the atmosphere in which he lived, and over which he had no control. Since these early beginnings, neither selective breeding of his animals, nor inventive skill has succeeded in freeing him from dependence upon the cooperation of his atmosphere. Nor has he been able to do anything to bend the atmosphere to his will.

As man's ingenuity perfected better and better vehicles, each in turn was more and more susceptible to changes in the characteristics of the atmosphere. His first attempt at improving these things with which nature had provided him was probably the erection of a crude sail upon a raft. With this vehicle he had already to be concerned about extremes of wind, both maxima and minima, whereas before his main concern with the floating log was only that sufficient rain should fall in which he could float it, and not so much that it would float away when unattended. With the coming of wheeled vehicles, he had to concern himself with having a firm footing upon which the wheel could turn. That part of his natural environment upon which he stood usually responded in some way to excessive rain or snow, or on the other hand to drought. The coming of the iron horse, as well as the automobile, called for bridges, themselves quite susceptible to destruction by the elements. The age of flight brought all the earlier problems together, and it was the development of the aviation industry that necessitated a parallel and equally rapid development in man's knowledge about the behavior of the atmosphere. The first ten years of the space age have only accentuated the necessith of continued effort in this direction.

Just as surely as a cloudburst could inconvenience prehistoric man by drowning his ox or floating away his log, as surely as a hurricane could demolish an entire fleet of ships, as surely as blizzards have marooned wagon trains and the modern diesel locomotive, as surely as a blanket of fog has stranded thousands of air travelers in the air terminals, - that sure we may be that the weather must be on its good behavior before spaceflights can be conducted with anything resembling regularity of schedule. When the elements are not cooperating, the vehicle must be protected therefrom.

In a sense it is ironical that man has perfected a machine with which he can circle the globe in one and one-half hours, or travel to the moon and back, completely outside the influence of the atmosphere, while he remains so vulnerable to its pranks, for the short distance of fifty or so miles, and a few minutes of flying time, plus endless hours needed to prepare his vehicle. The later generation of launch vehicles, because of their size, have had to be constructed so that they are less susceptible to the destructive effects of any strong winds and wind shears during the traverse of the jet stream layer in the atmosphere. There was a time when the 100-knot winds in the jet stream grounded most rockets. Today's models are much less vulnerable; most of them are capable of flying through a layer moving at 150 knots assuming an ordinary direction and wind shear.

This substantial gain in the rocket's capability to withstand a rigorous flight has been accompanied by an increase in complexity of the job of getting it ready to fly. Preflight preparation is now an exhausting operation. Many of the preflight operations are themselves weather susceptible. At the Kennedy Space Center, the Vehicle Assembly Building was supposed to take care of the weather exposure problem. It did, however, create a few of its own. That big box is a little too much for complete air conditioning. They count on opening the doors for ventilation, which is fine until a little wind of 15 or 20 knots comes along with a brief shower. One can readily calculate that something like 1000 gallons of water would come in those big doors during a quarter-inch rain accompanied by such a breeze. Of more concern than the amount of water on the deck is what it might get into immediately and what the resulting humidity might be a few hours later. Can you imagine the pendulum effect induced by a little breeze upon a cable block dangling from the rafters, 500 feet above? Unless someone is standing by every piece of machinery and equipment, it becomes essential that those doors come closed before it becomes rainy or windy. They don't slam shut with the same ease as a porch door. Nearly an hour is required when they are full open.

Moving an assembled Saturn V on a crawler was at one time expected to present the biggest meteorological forecast problem that would grow out of the mobile launcher concept. It has not proven to be so. An almost complete system was brought from the launch pad back to the Vehicle Assembly Building while Hurricane Alma passed by to the west of Florida in 1966. Peripheral winds attained speeds of up to 55 knots near the top of the launcher during that move, but no harm came to the vehicle or the launcher. Except for a hurricane-induced move, there is little chance that an assembled vehicle will make a move under such strong wind conditions. But careful planning is necessary to avoid inconveniences caused by winds of comparable velocity that are produced by strictly local summer storms.

Thunderstorms are now and have for sometime been of more concern than any other meteorological problems connected with large launch vehicles. A bad thunderstorm is at one and the same time just about all types of inclement weather wrapped into a single package: Driving heavy rain, strong gusty winds, sometimes hail, local flooding, and of course lightning. Any one of these conditions, lacking adequate preventive measures, could disrupt a well planned launch schedule for months. It is not hard to assess wind and water damage to space vehicles, but lightning is something else. Insidious current surges through complex electronic circuits have been known to invalidate months of prelaunch testing. Without going all the way back to incremental testing of components, one can never be quite sure that everything is in proper order following a lightning strike near a launch pad. Computers left operative during the passage of a lightning storm are especially susceptible. Putting one back in order rapidly drains the budget. Lightning, of course, poses a risk to personnel safety in the vicinity of a launch pad occupied by a launcher towering some 500 feet above the surrounding terrain. The risk to personnel dictates exclusion of traffic on or off the launcher during the passage of a lightning storm, and undoubtedly restricts many activities on the launcher. Sudden heavy rains or windstorms may easily catch parts of the space vehicle exposed in such a way as to result in heavy damage to costly equipment.

The many potential effects of meteorological phenomena upon spaceflight operations, particularly upon prelaunch preparations, call for continuous monitoring of changing weather events and continuous updating of forecasts to cut down on costs, to minimize time losses, and above all to prevent loss of life and costly equipment. Nothing can be done about the weather; it is necessary to take steps to minimize its effects. The important thing is to find a proper balance between the extremes of safety at any cost, and getting the job done as quickly as possible. It is in this realm that the meteorologist easily earns his pay - sometimes a year's pay - in a few brief moments.

Weather support of spaceport operations must satisfy a large range of user requirements. We will not concern ourselves with standard meteorological measurements of atmospheric parameters. These are not significantly different in scope, but more detailed in accuracy than the measurements made in support of aviation for the last 25 years or more. Neither will we be concerned with the standard forecast materials extensively available via national communication facilities. The meteorological support which is the subject of this paper is that which is peculiar to the requirements of space vehicles from the time they arrive at the Space Center until their launching. What needs to be provided is a continuous consultant service to the test supervisors, safety specialists, and support controllers. The meteorological supporting group needs to be bolstered by meteorological research specialists, capable of quick response to special requirements for climatic information, and probability information relative to meteorological events beyond the scope of reliable forecasting.

It will be the purpose of this paper to describe some of the facilities required to perform such a consultant service.

The test supervisors and support controllers need a broad scope of forecasts covering the very short range (1-2 hours) out to the long range (3-5 days), as well as everything in between. The very short period forecast is to permit door closings, elevator securing, lightning mast erection, swing arm retraction, and any one of a dozen or more securing operations, prior to the onset of inclement weather. Whenever any of these actions must be taken, some activity involving manpower and expensive equipment is effectively shut down. It is vital that such actions be taken only at the latest possible time. The forecaster-consultant must be kept aware of the configuration of vehicle and complex at all times in order to meet the deadlines for advance notification of a weather event. The long range forecast, on the other hand, finds a different application. It supports planning and work scheduling. The accuracy of the long range forecast is of course inferior to the short range. It cannot be applied in the same way. Here probability has its best application. If a reliable probability can be assigned to a forecast, the test supervisor or the support controller can weigh the advantages and disadvantages of certain actions that may be taken to minimize the effects of weather. He may wish to schedule overtime to complete an operation, rather than risk weather interruption that might invalidate a test. He may wish to delay an important operation that would put the space vehicle into an undesirable configuration to survive a possible weather event. He may, at times, even need inclement weather to prove out a system designed to protect against weather. The assignment of probability to a forecast is almost a science in itself. Probabilities quoted in the forecasts which are available to the general public are sometimes described as a measure of a forecaster's own confidence. Up to a point this may be true, but generally speaking, the possibility of a weather event occurring at a specific time and place is related to a number of factors, some of which defy objectivity. To be able to apply a reliable probability to a forecast, a thorough analysis of the distribution of errors committed in earlier forecasts is necessary over a considerable period of time. This is where the meteorological research specialist comes in.

Continuous monitoring of local weather behavior and updating of the short term forecast is the most demanding in manpower and facilities. There is no substitute for visual observation of weather phenomena of the kind that may be hazardous to spaceport operations. Given daylight conditions, the human eye can evaluate the threat presented by a local weather event, such as a growing cumulonimbus cloud, better than any piece of instrumentation alone. Electronic equipment cannot perform the same function until the cloud has already become a weather producer. For some purposes electronic equipment is more reliable than the observer's eye, especially at night. Just as the ceilometer took over the estimating of cloud heights and the transmissometer the estimation of visibility at airports during the last 25 years, so too electronic sensors are assisting the observer at the Space Center in evaluation of weather problems. The weather radar is the most important single piece of equipment for improving the observer's capability for evaluating and predicting weather events on the very short term. But the radar has its limitations. It sees but little more than precipitation. It cannot reliably detect the threat of lightning. It sometimes detects what isn't even there, and it is subject to outages. Electronic systems whose only function is evaluation of the threat of lightning have been under development for several years. As might be expected, none of these systems represents a complete solution to the lightning problem; characteristic of all of them is their inability to give more than very little advance warning of lightning danger, except when applied to a moving storm. Nonetheless the high susceptibility to lightning damage around a spaceport necessitates use of such equipment to supplement visual observation and other detection systems. When visual observation is impossible, they are indispensable. The sferics system gives a reliable indication of the location of lightning strikes that might not otherwise be known. Its usefulness is rather limited to remote storms that might move toward a susceptible area. A network of potential gradient meters is of inestimable value in an area such as Florida, where many lightning storms grow to maturity and expend themselves without moving as much as five miles. If such a growing storm is overhead, even visual observation of its growth is impossible, and the potential gradient meter is the only indicator of the impending first stroke. With a network of such meters, the relative intensity of several such storms in an area can be anticipated. The potential gradient meter alone is only a little better than nothing in the case of the rapidly developing storm. First lightning often comes less than five minutes after initial displacement of its indicator, and on the other hand in many cases it only signals false alarms. This only emphasizes the necessity for the man-machine combination working together to evaluate the lightning threat.

An extensive network of wind and temperature sensing equipment, computer driven, is vital to the prediction of dispersion characteristics pertinent to the safe handling of toxic or radioactive materials. Information gathered on such a network has application to other short period forecast problems. Strictly local winds influence in some degree the precise location at which atmospheric disturbances such as showers or thunderstorms evolve. The march of temperature influences the time of day at which such phenomena may begin.

In addition to prelaunch and launch support, space flight also requires forecasts for other parts of the world, specifically for planned and possible emergency landings and for those scientific experiments which depend on the presence of specific weather conditions in various parts of the world.

It is not economical or logical to concentrate the forecasting for such other areas of the world at the launch port, particularly since the flights are controlled from the NASA Manned Spacecraft Center. In providing the weather support for NASA manned spaceflight programs, the Weather Bureau Spaceflight Meteorology Group has three supporting offices in addition to those at Kennedy Space Center and Manned Spacecraft Center. These include facilities co-located at the National Meteorological capable of flying through a layer moving at 150 knots assuming an ordinary direction and wind shear.

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Center outside Washington, D.C. and at the National Center for Tropical Meteorology at Miami, plus a liaison meteorologist at the Weather Bureau Regional Office in Honolulu.

Supporting meteorological research and climatological investigations are also functions of all offices of the Spaceflight Meteorology Group, particularly in non-mission periods. Some of this investigative work must be done on short notice at the space center. Other studies are done to take advantage of the data, more complete facilities and research skills of the supporting offices. The companion presentation is an example of such applied research carried out by two of the meteorologists at the Miami office of the Spaceflight Meteorology Group.